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<p>Research during the period of this report was conducted at Yale University. James McCambridge conducted research on deposition and characterization of high temperature superconductor films. A number of configurations for sputter deposition of films were tested, including three-source co-sputtering with the guns facing, and with the guns off-axis, from the growing film, and single composite-target sputtering. The best film properties were obtained with off-axis, single target sputtering onto a heated substrate. Further research will be carried out jointly with researchers at the Westinghouse Science and Technology Center. McCambridge will spend time there as a visiting researcher.</p>					
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Annual Technical Report for AFOSR 90-0306

(for period June 1, 1990-May 31, 1991)

During the first year of this program, graduate student Jim McCambridge carried out research at Yale University preparing him for his research collaboration with Westinghouse Science and Technology Center. In addition, he has taken courses as a second year graduate student. The research undertaken is described below. McCambridge began his actual tenure at Westinghouse in June, 1991. Research accomplished there will be presented in our next Technical Report.

McCambridge has conducted research on deposition of high  $T_c$  superconductor films using a multisource sputter deposition system. (The purchase of that system and the balance of McCambridge's fiscal support was provided by a separate research grant.)

McCambridge began his participation in this program after the deposition system was installed and initially characterized. The initial configuration of the deposition system allowed deposition from 3 sources. MgO or SrTiO<sub>3</sub> substrates were used. Material analysis was carried out to determine film composition, uniformity, and microstructure. The techniques employed were inductively-coupled plasma emission (ICP), electron microscopy (SEM), and energy dispersive x-ray analysis (EDAX). In addition, some materials analysis was conducted at the University of Connecticut with Rutherford backscattering (RBS). At Yale, the electrical and magnetic superconducting properties were studied using measurements of electrical conductivity and ac susceptibility. To conduct the experiments at Yale, apparatus developed previously for low-temperature superconductor studies was modified for higher temperature operation, for use in this program.

Initially, we deposited films onto heated MgO substrates using simultaneous sputtering (co-sputtering) from three metal targets: Yttrium, Copper, and a Barium-copper alloy. After a significant number of depositions were carried out to optimize film composition and to maximize transition temperature, we began deposition onto substrates of SrTiO<sub>3</sub>. These substrates allowed higher transition temperatures and films with lower resistivities, a desirable property.

Our best films gave  $T_c = 85K$  for  $R=0$ . These films were deposited onto heated strontium titanate substrates,  $T_s \approx 700^\circ C$ , in the presence of a partial pressure of 0.2 mTorr of oxygen in a typical argon pressure of 7.5 mTorr. (The actual oxygen pressure *at the substrate* was likely an order of magnitude higher, since the oxygen was injected directly at the substrate. This also minimized the

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exposure of the metal targets to the oxygen.) We would have preferred a higher partial pressure of oxygen, but were limited to much less than 1 mTorr to prevent oxidation of the Ba-Cu target during sputtering. Significant oxidation of the target at  $p_{\text{oxygen}} > 1$  mTorr led to deposition rates which drifted with time, altering the film stoichiometry. We thus had to work at lower oxygen partial pressures.

We found that ion bombardment during growth was causing structural damage which degraded film transition temperatures from those which were achieved with other techniques. The sputtering conditions used a pressure of  $\approx 8$  mTorr. At this pressure, the mean free path for ions is long. Thus, any negative oxygen ions created, for example, at the Ba-Cu target, will bombard the sample, creating structural defects and reducing film crystallinity. We have only indirect evidence for this effect. However, the evidence was strong enough that we sought to develop a deposition technique which did not bombard the substrate *during* film deposition.

The first approach we tried in order to avoid substrate bombardment was to use a composite target consisting of  $\text{YBa}_2\text{Cu}_3\text{O}_7$  and a sputter 'gun' with a high strength magnet. The use of a high strength magnet was claimed to reduce the target bombardment during deposition. (This claim was made by a researcher at the Lesker Co. laboratory, where our deposition system had been manufactured.) The composite target faced the substrate, so this was an *on-axis* geometry, as in the 3-source co-sputtering described above. We found that substrate bombardment by the source having a high strength magnet was probably lower, but was still unacceptable. The film compositions showed clear evidence of substrate bombardment, and the dependence of deposition rate on target-to-substrate distance was much stronger than usual.

The second approach we tried was to use simultaneous sputtering from three targets, Y, Cu, and BaCu, but with the sputter sources facing *off-axis* to the substrate. This appeared to eliminate the ion bombardment experienced when the target faced the substrate. Transition temperatures improved to near 90K, and some transitions were narrow. Unfortunately, it is difficult to reproducibly control the film stoichiometry from run to run, due to the complexity of the system. Thus, film properties were not as reproducible as desired. We therefore explored a third approach, one which turned out to work quite well.

The approach we finally adopted was that of *off-axis composite target* sputtering. A single composite target was employed. Film quality was very good, with transition temperatures near 90K. Moreover, the reproducibility was good, and is still improving. We have therefore adopted this technique as our

standard method. Work by another graduate student, more senior to McCambridge, continues at Yale.

What was accomplished at Yale during the past year was for McCambridge to become familiar with the full range of film deposition and processing techniques. He also learned how to make most of the needed electrical measurements on films, and to participate in the materials analysis. Since he was also taking courses, the research accomplished fully met expectations.

McCambridge will spend the months of June - Sept. 1991 at the Westinghouse Science and Technology Center with the research group under Dr. John Talvacchio. He plans to work there on the superconductivity issues related to high Tc microstructures formed on step edges. This will involve both materials issues, like those outlined in the original proposal, and new superconductivity issues which were not fully formulated at the time of the submission of the proposal. That work will be summarized in our Final Report.



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